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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Advanced Civil/Military Aircraft (ACMA) is envisioned as an advanced-technology cargo aircraft with the potential for fulfilling the needs of both military airlift and commercial air freight in the 1990s and beyond. The ultimate goal of the Design Options Study is the development of fundamental information regarding both the military and commercial cost and effectiveness implications of the most significant transport aircraft functional design features. This volume, the Executive Summary of the Design Options Study (Cont'd)

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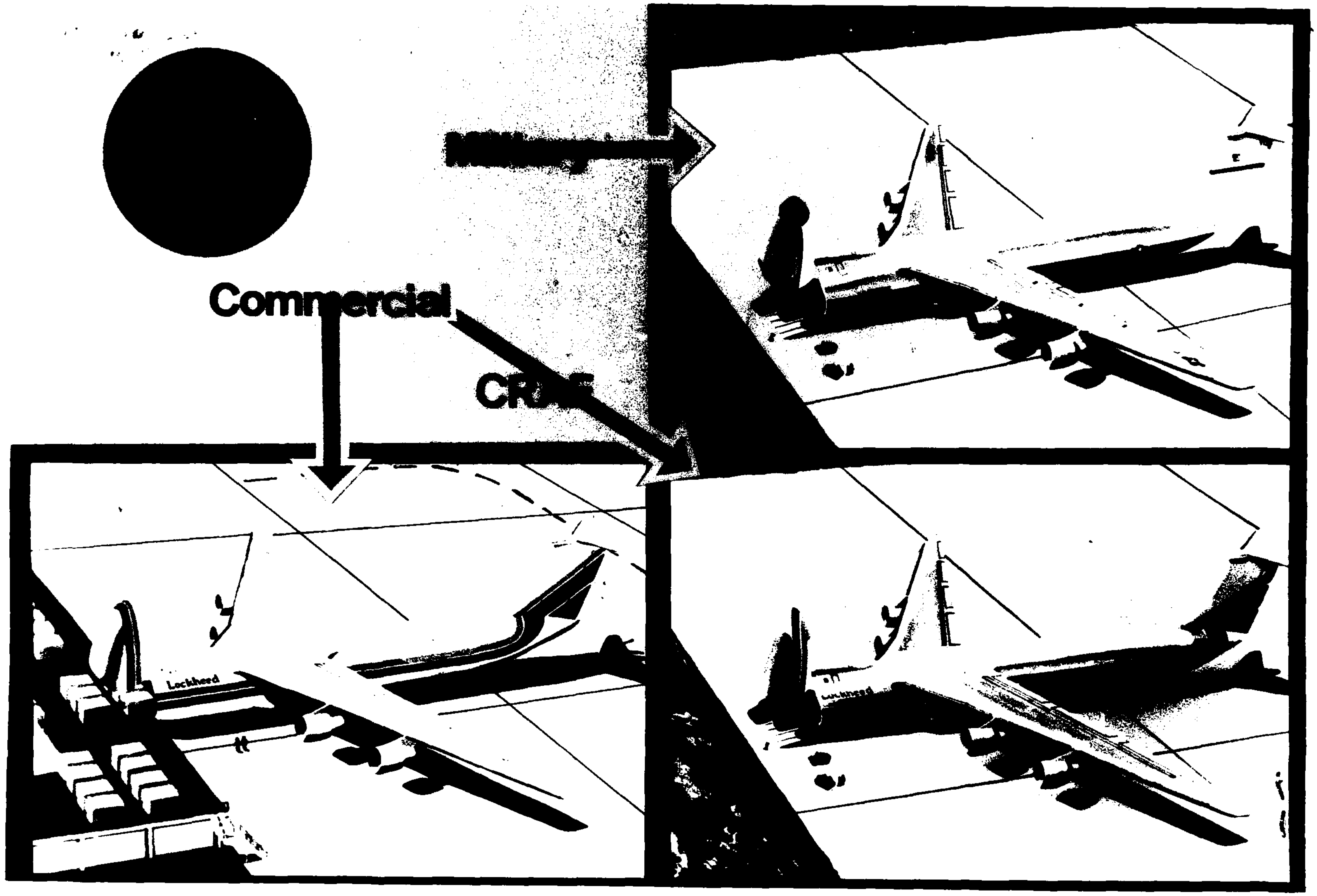
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DESIGN OPTIONS STUDY

Volume I: Executive Summary

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APPROVED BY: R H Lange

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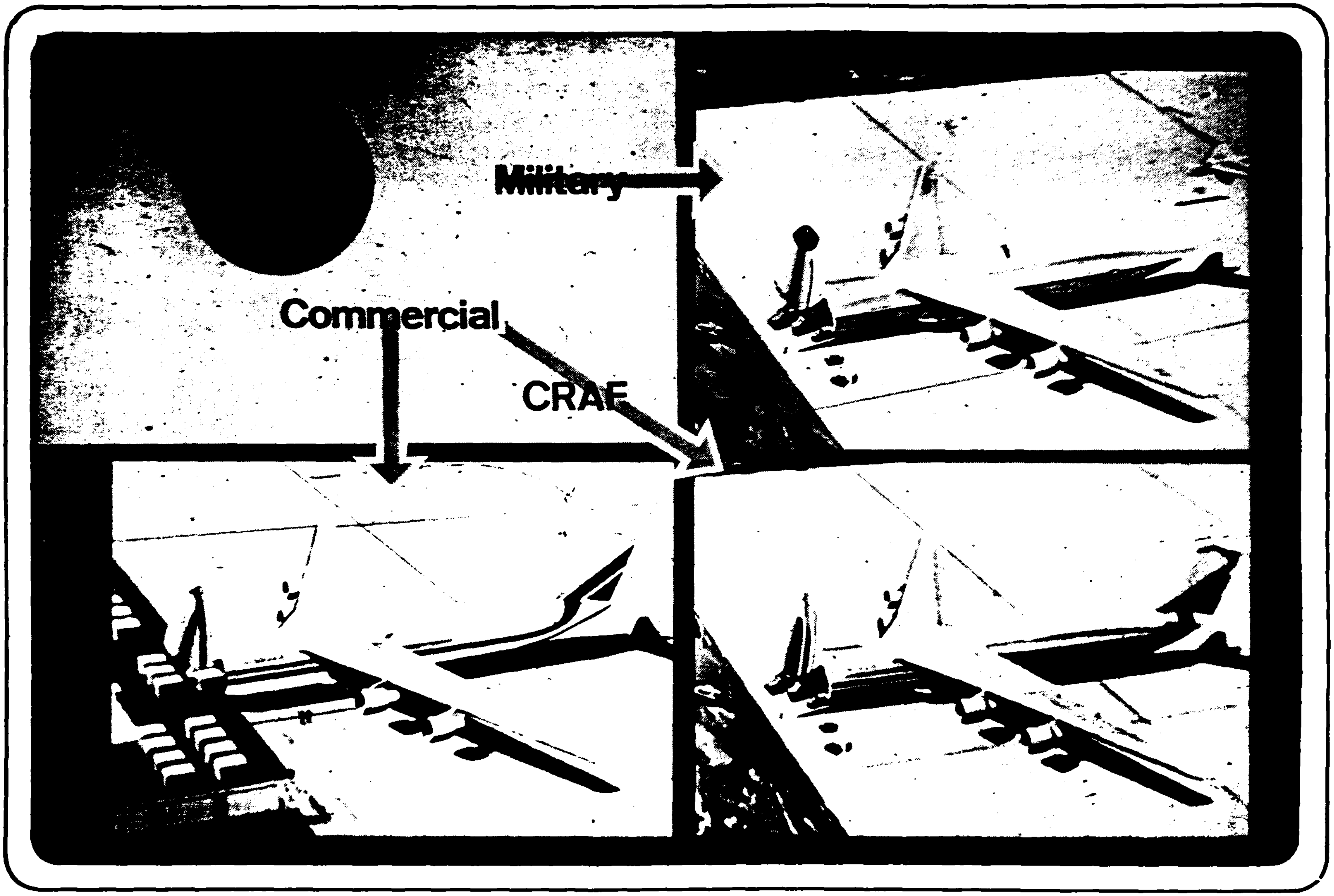
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FOREWORD

The Design Options Study was performed by Lockheed-Georgia for the Air Force Aeronautical Systems Division, Deputy for Development Planning, under Contract F33615-78-C-0122. This final report for the effort is presented in four volumes:

Volume I	Executive Summary
Volume II	Approach and Summary Results
Volume III	Qualitative Assessment
Volume IV	Detailed-Analysis Supporting Appendices

A fifth volume, describing the privately-developed analytical techniques used in this study has been documented as Lockheed Engineering Report LG80ER0015. This volume, which contains Lockheed Proprietary Data, will be furnished to the Government upon written request for the limited purpose of evaluating the other four volumes.

The Air Force program manager for this effort was Dr. L. W. Noggle; Dr. W. T. Mikolowsky was the Lockheed-Georgia study manager. Lockheed-Georgia personnel who participated in the Design Options Study include:

H. J. Abbey	Configuration Development
L. A. Adkins	Avionics
H. A. Bricker	Cost Analysis
E. W. Caldwell	Configuration Development
W. A. French	Propulsion and Noise Analysis
J. C. Hedstrom	Mission Analysis
J. F. Honrath	Aerodynamics
R. C. LeCroy	Mission Analysis
E. E. McBride	Stability and Control
A. McLean	Reliability
T. H. Neighbors	Maintainability
J. M. Norman	Commercial Systems Analysis
J. R. Peele	Mission Analysis
A. P. Pennock	Noise Analysis
C. E. Phillips	Maintainability
R. L. Rodgers	Mission Analysis
R. E. Stephens	Structures and Weights
R. L. Stowell	Mission Analysis
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Program management of the Design Options Study was the responsibility of the Advanced Concepts Department (R. H. Lange, manager) of the Advanced Design Division of Lockheed-Georgia.

EXECUTIVE SUMMARY

The Advanced Civil/Military Aircraft (ACMA) is conceived as an advanced-technology transport aircraft with the potential for fulfilling both the U.S. need for military airlift and the worldwide need for commercial airfreight in the 1990s and beyond. This volume summarizes the work performed by Lockheed-Georgia on the ACMA Design Options Study for the Aeronautical Systems Division, Deputy for Development Planning.

INTRODUCTION

The following paragraphs review the pertinent background of the ACMA concept (initially called C-XX) and describe the major objectives and tasks of this study. An overview of the principal findings of the study and a roadmap of the Executive Summary are also presented.

Background

In recognition of the military need for additional strategic airlift, the Military Airlift Command issued a Statement of Operational Need (SON) for a new intertheater airlift vehicle in August 1979. That a substantial commercial market also exists for a long-range aircraft with a payload capability greater than that presently available is suggested by recent NASA-sponsored efforts known as the Cargo/Logistics Airlift Systems Studies (CLASS) as well as the Issues of Commonality Study performed by Lockheed-Georgia for the Air Force.

The ACMA concept has evolved in response to these projected requirements. The potential benefits of a joint civil/military transport are manifest. They include:

- Lower average unit flyaway costs for both civil and military users resulting from larger production quantities.
- Amortization of development costs over a greater number of units.
- Greatly enhanced emergency airlift capability provided by commercial aircraft serving in the Civil Reserve Air Fleet (CRAF).

- Possible cost-savings by the commercial maintenance of organic military aircraft.

These expected benefits should lead to an aircraft that is superior--in terms of cost-effectiveness and profitability, respectively--to any other cargo aircraft available to the military or to commercial operators.

Objectives and Tasks

The Design Options Study examines the design aspects of a joint civil/military transport aircraft which is assumed to incorporate a level of advanced technology appropriate for a system with an Initial Operational Capability (IOC) in 1995.

The focus of this effort is on those transport aircraft functional design features that might tend to impede development of a system suitable for both military and commercial use. Specifically, the study identifies the design features that are likely to be most troublesome from the viewpoint of commonality. For each such design feature however, design options exist that may enhance the concept of a joint aircraft program. A key element of this work is the development of detailed estimates of the cost and effectiveness implications of selected design options in both military and commercial contexts. A final objective of this effort is to synthesize the results, making them particularly useful to both Air Force decision makers and potential civil operators.

The Design Options Study consists of two primary tasks. The first is a qualitative assessment of all the aircraft design features that are particularly important to the commonality concept. Design options are identified for each of these features, and in most cases in which military and commercial desires diverge, the desirable options for each are identified. Quite often, one or more potentially interesting compromises are also identified. By qualitatively evaluating the potential of each design option in terms of its prospects for enhancing commonality, we are able to compile a prioritized list of design features and associated options for more detailed analysis.

The second task then, is the detailed analysis of those design options considered to be of greatest significance. Our approach here is to completely redesign the baseline aircraft after incorporating each design option of interest. Estimates of changes from the baseline are then generated for military cost, effectiveness, and flexibility, and for commercial economics. A careful synthesis of this information provides insights into the attractiveness of the option.

Overview of Findings

Our principal findings in this work relate to both the design aspects of a joint civil/military transport, and to the overall merit of the commonality concept. In terms of the former, the present study suggests that the desirable military and commercial design features are generally compatible, at least for the aircraft size and technology level investigated. Furthermore, only relatively small penalties are associated with those few features in which a civil/military incompatibility exists.

For the ACMA concept to be successful, however, it must provide considerably better economics in commercial operation than any of the available alternatives. Our work suggests that reductions in direct operating costs (DOC) approaching 40 percent, relative to the best contemporary commercial aircraft, are achievable. These superior ACMA commercial economics are possible through a blending of advanced technology, economies of scale, and careful design as discussed later in this Executive Summary.

Executive Summary Roadmap

The first task of the Design Options Study, the qualitative assessment, is discussed in terms of the contextual framework and the technique employed in the assessment. The design features and associated options examined in the assessment and the design options subjected to detailed analysis are listed.

Our approach to the detailed analysis, including an illustrative example, is then presented. Finally, the results of these analyses are summarized and retrospectively interpreted.

This Executive Summary concludes with some major observations based on the work to date, including the present perspective on the relative merits of a joint program.

QUALITATIVE ASSESSMENT

A cursory examination of any list of aircraft design features that could affect the ACMA leads to the realization that it is a practical impossibility to examine every configuration that represents a plausible combination of options. The purpose, therefore, of the qualitative assessment is to identify the most appropriate options for more detailed analyses and to establish a logical order for these analyses.

To provide structure to the qualitative assessment, a contextual framework is developed to assure that adequate consideration is given to all pertinent design features and that all significant interdependencies are taken into account.

Contextual Framework

The representation of the aircraft design process in Figure 1 highlights the initialization parameters which ultimately determine the characteristics of the system. All of the steps usually associated with system design have been collapsed into a single block labeled "Synthesis and Optimization." As illustrated in Figure 1, three types of initialization parameters are required:

- The required system capabilities.
- The assumptions regarding the environment in which the aircraft will ultimately operate (e.g., the technology level established for the time frame of interest, fuel cost, etc.).
- The objective function (e.g., minimum cost, minimum gross weight, etc.) that forms the basis for system optimization.

Given that all three types of parameters are wholly specified by the customer, the design process can, conceptually at least, generate the optimum system.

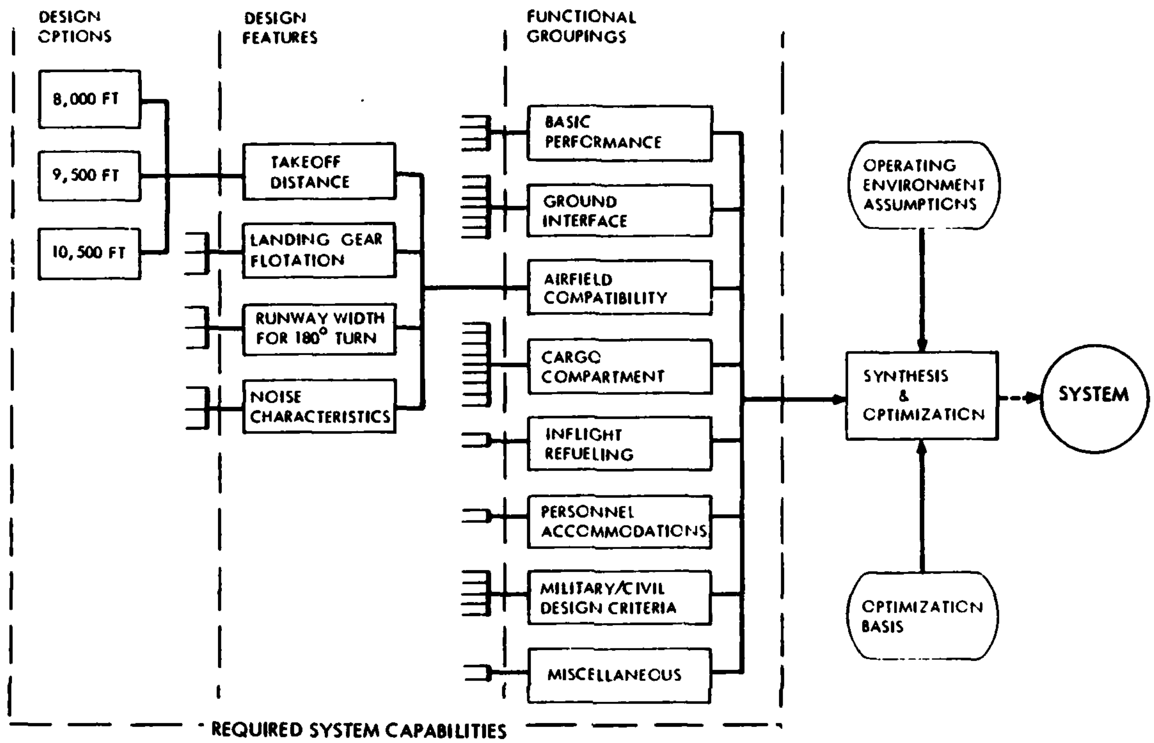

Figure 1. Contextual Framework for the Qualitative Assessment

Figure 1 further illustrates how required system capabilities can be expressed in terms of eight functional groupings, with two or more design features characterizing each grouping. For example, as shown in Figure 1, takeoff distance, landing gear flotation, runway width for a 180° turn, and noise characteristics are the design features associated with the airfield-compatability functional grouping. In this context, various design options are available for each feature, as illustrated for the takeoff distance feature. (Throughout this discussion, the preceding distinction between "design feature" and "design option" is consistently used.)

Assessment Technique

Given the contextual framework just described, the qualitative assessment proceeds as follows. For each design feature, design options are identified that represent what is generally thought to be desirable from a military viewpoint, what is thought to be desirable from a commercial viewpoint, and any potentially interesting compromises. Of particular interest as a compromise, is the possibility of providing the desirable military feature through the use of a kit that would not normally be installed on the civil aircraft until they are activated as part of CRAF. Table 1 lists the 37 selected design features and their associated options that are considered in the qualitative assessment.

The design options for each of the relevant design features listed in Table 1 are then subjectively assessed in terms of their anticipated impact in each of the following areas:

- Military Considerations
  - Life Cycle Cost
  - Mission Effectiveness
  - Mission Flexibility

- Commercial Considerations
  - Direct Operating Cost
  - Indirect Operating Cost
  - Market Expansion Potential (including return on investment)

During the assessment, options were combined when appropriate, inconsistent and relatively insignificant combinations were eliminated, and those remaining were prioritized in terms of their expected significance.

Most Significant Design Features

Table 2 lists the principal product of the qualitative assessment--the design features and associated options subsequently examined in detail in this effort.

TABLE 1

FUNCTIONAL FEATURES AND ASSOCIATED DESIGN OPTIONS INCLUDED IN QUALITATIVE ASSESSMENT

BASIC PERFORMANCE

- o Design Range
  - 6500 nm (CONUS - Middle East)
  - 5500 nm (transpacific)
  - 4000 nm (transpolar)
  - 3500 nm (transatlantic)
  - 2500 nm (transcontinental)
- o Design Payload
  - 495,000 lb
  - 450,000 lb
  - 405,000 lb
  - 360,000 lb
  - 315,000 lb
- o Maximum Structural Payload
  - Corresponds to design range (i.e., the design payload)
  - Corresponds to a 3500 nm flight with takeoff at maximum gross weight
  - Corresponds to a 2500 nm flight with takeoff at maximum gross weight
- o Cruise Mach Number
  - 0.70
  - 0.78
  - 0.85

GROUND INTERFACE

- o Cargo-Compartment Floor Height
  - 8 ft kneeled (level), 13 ft unkneeled
  - 13 ft (no kneeling)
  - 18 ft (no kneeling)
- o Loading/Unloading Apertures
  - Front and rear
  - Front only
  - Rear only
  - Front and side
- o Vehicle Loading/Unloading Mechanism
  - Partially removable ramps
  - Fully removable ramps
  - Elevator
  - Crane
- o Container/Pallet Loading/Unloading System
  - Ground loader
  - Integral elevator
  - Integral crane
- o Air Drop Provisions
- o Loading Stabilizer Struts
- o Ground Refueling Provisions

AIRFIELD COMPATIBILITY

- o Takeoff Distance
  - 8,000 ft
  - 9,500 ft
  - 10,500 ft
- o Landing Gear Flotation
  - LCG I (LCNs greater than 100)
  - LCG II (LCNs between 76 and 100)
  - LCG III (LCNs between 51 and 75)
- o Runway Width for 180° Turn
  - 150 ft
  - 200 ft
  - 300 ft
- o Noise Characteristics
  - No special acoustic treatment
  - Treatment for aircraft to conform to FAR 36 Stage 3 limits
  - Treatment and engine cycle selection for even lower noise levels to permit "curfew free" operations

CARGO COMPARTMENT

- o Cargo Compartment Planform Shape
  - Tapered forward (19 ft width) and aft (13 ft width)
  - Full width (27.3 ft) forward and aft
  - Full width (27.3 ft) forward and tapered aft (13 ft width)
- o Cargo Envelope
  - 13.5 ft for entire compartment length
  - 11 ft for entire compartment length
  - 13.5 ft forward of wing carry-through, 11 ft aft

TABLE 1
FUNCTIONAL FEATURES AND ASSOCIATED DESIGN OPTIONS INCLUDED IN QUALITATIVE ASSESSMENT (CONTINUED)

- Floor Strength
  - Integral hard floor
  - Commercial floor with hard-floor kit
  - Commercial floor with slave pallets
- Sub-Floor Strength
  - Integral for military loading
  - Integral for commercial loading with military beef-up kit
- Vehicle Tiedowns
  - Integral tiedown rings
  - Kitted tiedown rings
- Container/Pallet Handling/Restraint System
  - Flip-flop rollers, stowable and adjustable lateral restraint rails/locks, stowable and adjustable fore/aft locks, and stowable powered-drive units
  - Fixed rollers, laterally adjustable restraint rails/locks, stowable and adjustable fore/aft locks, and fixed powered-drive units
  - Overhead crane with corner-lock restraints
  - Externally-powered shuttle loader with corner-lock restraints
- Pressurization
  - 8,000 ft (8.2 psi pressure differential)
  - 18,000 ft (4.6 psi pressure differential)
  - Unpressurized (zero pressure differential)
- Cargo-Stick Width
  - 8.0 ft (96 in)
  - 8.5 ft (102 in)
  - 9.0 ft (108 in)
- Cargo-Compartment Length
  - Based on military-unit loadability
  - Based on commercial containerized payload density

INFLIGHT REFUELING

- Inflight Refueling Technique
  - Receptacle kit
  - Probe kit
- Tanker Kit Provisions
  - Boom only
  - Drogue only
  - Boom and drogues
  - None

PERSONNEL ACCOMMODATIONS

- Relief-Crew Provisions
  - Integral relief-crew compartment
  - Containerized relief-crew compartment
- Passenger Provisions
  - Integral troop compartment
  - Containerized troop compartment
  - Integral passenger/troop compartment
  - None (except cargo-compartment bench seats for vehicle drivers)

MISCELLANEOUS

- Maintenance/Support Concept
  - All organic
  - All contractor
  - Hybrid organic/contractor
- Avionics
  - Common military/commercial suite
  - Commercial suite with hard points and permanently installed wiring for military peculiar avionics
- Subsystem Motive Power

MILITARY/CIVIL DESIGN CRITERIA

- Noise Regulations
- Engine Emissions
- Performance Specifications
- Certification Procedures
- Design Limit-Load Factor
  - Commercial
  - Military peacetime
  - Military contingency
- Service-Life Specification

TABLE 2
DESIGN OPTIONS AND ASSOCIATED MODEL NUMBERS

GROUP	DESIGN FEATURES	DESIGN OPTIONS	MODEL NO.	DERIVED FROM
I	Design Payload	495,000 lb	-100	-
		450,000 lb	-111	-100
		405,000 lb	-112	-100
		360,000 lb	-113	-100
		315,000 lb	-114	-100
II	Loading/Unloading Apertures	Front & rear with ADS kit provisions	-200	-113
		Front only with no air drop capability	-211	-200
	Planform Shape of Cargo Compartment	Tapered forward and aft	-200	-
		Full width Forward and aft	-221	-222
		Full width forward and tapered aft (with airdrop capability)	-222	-200
		Full width forward and tapered aft (with no airdrop capability)	-223	-211, -222
	Floor Height	8 ft kneeled and 13 ft unkneeled	-200	-
		13 ft, no kneeling capability	-231	-200
III	Takeoff Distance/ Gear Flotation	8,000 ft/LCG III	-313	-323
		9,500 ft/LCG III	-323	-200
		10,500 ft/LCG III	-333	-323
		9,500 ft/LCG II	-322	-323
		10,500 ft/LCG II	-332	-333
	Noise Characteristics/ Engine-Out Climb Gradient	No special acoustic treatment/2.5 percent	-313, -323, -333	-
		Conform to FAR 36/3.0 percent	-343, -353, -363	-313, -323, -333
IV	Cargo Envelope (Maximum Height)	Constant 13.5 ft	-400	-223
		Constant 11 ft	-411	-400
	Passenger Provisions	None (except bench seats in cheek)	-400	-
		Integral high density passenger accommodations	-421	-400
		Integral medium density passenger accommodations	-423	-400
		Modular high density passenger accommodations	-423	-400
		Integral and modular medium density passenger accommodations	-424	-422
	Maximum Structural Payload	Corresponds to design range (i.e., the design payload)	-400	-
		Corresponds to 3,500 n mi flight with takeoff at maximum gross weight	-431	-400
		Corresponds to 2,500 n mi flight with takeoff at maximum gross weight	-432	-400
	Service-Life Specification	30,000 hrs, military mission profiles	-400	-
		60,000 hrs, commercial operational profiles	-441	-400
	Pressurization	8,000 ft (at 40,000 ft flight altitude)	-400	-
		18,000 ft with baseline fuselage cross section	-451	-400
		18,000 ft with -411 fuselage cross section	-452	-411

The features are listed in Table 2 in order of their anticipated significance. We divided the features into four groups with the intent of redefining the baseline aircraft after completing the Group I analysis as well as after the Group II analysis. Redefinition of the baseline is an attempt to minimize the effect of the interdependent nature of the features. That is, the relative attractivness of some of the design options in Group II (e.g., inclusion of an aft door) is dependent to some extent on the design payload. Redefining the baseline aircraft assures that subsequent features are examined in the context of the most promising configuration, based on the analysis performed to that point.

Also shown in Table 2 is the model numbering scheme employed in the present study.

DETAILED ANALYSES

Our approach to the detailed analyses of the design options listed in Table 2 is structured to provide the most credible estimates possible of the effect of each design option on the ACMA system. The following general procedure was used for each design option:

- The option of interest is first incorporated into the baseline aircraft which, in many instances, requires substantial redesign effort.
- The modified baseline aircraft is then resized to provide the minimum gross weight configuration.
- Specialists in structures, aerodynamics, propulsion, and stability and control then validate the new configuration. Based on their recommendations, a final resizing may be necessary.
- Detailed estimates of military life-cycle costs and commercial economics can then be generated for the new configuration.
- Finally, the mission effectiveness and flexibility implications of the new configurations are developed.

The above procedure was applied to each of the design options listed in Table 2. An illustrative result of this analysis is presented later in this Executive Summary.

Summary Results

We noted earlier that our analysis reveals that the desirable military and commercial features for the ACMA tend to be compatible. Of all the features and options considered qualitatively (Table 1) and later quantitatively (Table 2), only those listed in Table 3 appear to resist civil/military commonality. Table 3 separates these troublesome features into two categories: "Definite Hindrances" to commonality, in which military and commercial interests are essentially at loggerheads; and "Possible Hindrances" in which the difference between what is desirable militarily and commercially is not so readily apparent.

Most prominent in the definite hindrance category is the cargo compartment floor height. In our work, this feature translates to whether or not the ACMA should incorporate a kneeling landing gear. As long as the ACMA is compatible with 747-type loading/unloading facilities, there is no foreseeable requirement to have lower cargo floor heights for the civil freighter version.

TABLE 3
DESIGN FEATURES RESISTING CIVIL/MILITARY COMMONALITY

	% PENALTY	
DESIGN FEATURE	CIVIL*	MILITARY**
DEFINITE HINDRANCES		
- Cargo-Compartment Floor Height	2.6	6.1
- Noise Characteristics/Climb Gradient	N/A	2.5
- Service-Life Specification	N/A	0.9
POSSIBLE HINDRANCES		
- Landing Gear Flotation	1.8	O/C
- Passenger Provisions	O/C	2.7
- Cargo Accommodation System	?	?

*Penalty in commercial economics if militarily-desirable feature is incorporated in basic configuration.

**Penalty in military cost-effectiveness if commercially desirable feature is incorporated in basic configuration.

The military requirement for a vehicle drive-on, drive-off capability however, necessitates ramps and ramp extensions which become quite cumbersome if the cargo floor is very high off the ground. Thus, an aircraft designed with a 13-foot cargo floor height (without kneeling capability) results in a military cost-effectiveness penalty of 6.1 percent, when compared to that same aircraft designed instead with an 8-foot cargo floor height provided by its kneeling capability. However, the civil operator pays a 2.6 percent penalty in DOC for the more complex kneeling landing gear. This feature, therefore, represents a definite conflict between the desires of the civil and the military operators of the ACMA.

The solution to the preceding dilemma may be fairly straightforward, however. Where aircraft produced exclusively for military use would incorporate a kneeling landing gear, commercial aircraft would not. But, when activated in a CRAF mobilization, ramp extensions would be installed on the commercial aircraft to accommodate military airlift needs. Such a strategy maintains the viability of the commonality concept while imposing only modest penalties on the military usefulness of the commercial aircraft.

The second and third features shown in Table 3 in this category reflect a distinctly different situtation. In these cases, achieving the FAR 36, Stage 3 noise regulations, the commercial engine-out climb gradient, and providing at least a 60,000-hour commercial service life are, in our view, essential if the ACMA is to be a commercial success. (Hence, the N/A--Not Applicable--notation for quantifying the civil penalty.) In these instances, the penalties in cost-effectiveness must be accepted by the military as a necessary compromise which appears unavoidable if commonality is to be achieved.

The features shown in Table 3 as "Possible Hindrances" involve much more subjective judgments. Consider first, landing gear flotation. From a military viewpoint, the desirability of a flotation capability somewhat better than that of the C-141 seems obvious (i.e., LCG III capability is highly desirable). Yet, a military airplane with a flotation capability comparable to that of the DC-8-63F (LCG II) may still be quite useful--despite being much less flexible than the LCG III alternative. That is, LCG II in the military case involves a difficult-to-quantify opportunity cost (O/C). Whether or not

the poorer LCG II flotation is desirable commercially is also open to question. Such a capability saves only 1.8 percent in DOC while eliminating the possibility of operating into and out of about half the world's airports thought to be of commercial significance for the ACMA.

The passenger provisions feature represents the reverse situation. In this instance, not providing passenger provisions for combi operations could preclude some apparently profitable commercial operations (hence, an opportunity cost). Providing such provisions in the military aircraft, however, does not appear cost-effective because cost-effectiveness analysis cannot reflect the benefits of moving troops in commercial-quality accommodations rather than in an austere, troop-pallet mode.

The last item shown in Table 3 is the cargo accommodation system. This feature has not been analyzed in detail in the current work because of time and resource limitations. However, we suspect that penalties are on the order of a few percent for both cases.

To summarize, Table 3 demonstrates that only a few transport aircraft design features tend to resist the concept of a joint civil/military airplane. Furthermore, those features that do resist commonality appear to represent only modest penalties in system cost--and these mainly to the military.

Some Retrospective Considerations

The concept of a joint civil/military aircraft is not new. Indeed, the ACMA concept dates to at least 1974, although commonality of military and civil cargo aircraft was first suggested in the 1950s. Thus, the concept has been examined in numerous previous studies, usually with the conclusion that commonality may entail unacceptable penalties. Why then have we arrived at essentially the opposite conclusion?

In retrospect, three elements seem to be of particular importance to the ACMA concept. Two of these are the advanced technology and economies of scale applied in the present effort. When combined with the third element, a careful design process, they appear to provide the means for overcoming the commonality problem, as discussed below.

Figure 2 illustrates the technology level that has been assumed for the Design Options Study. The most significant technology assumption is the use of composite resin-matrix materials, mainly graphite/epoxy, in both primary and secondary structure. The result is that composites account for 60 percent of the structural weight of the aircraft. Such a level of composite utilization will require aggressive technology development to assure its availability by the 1990s.

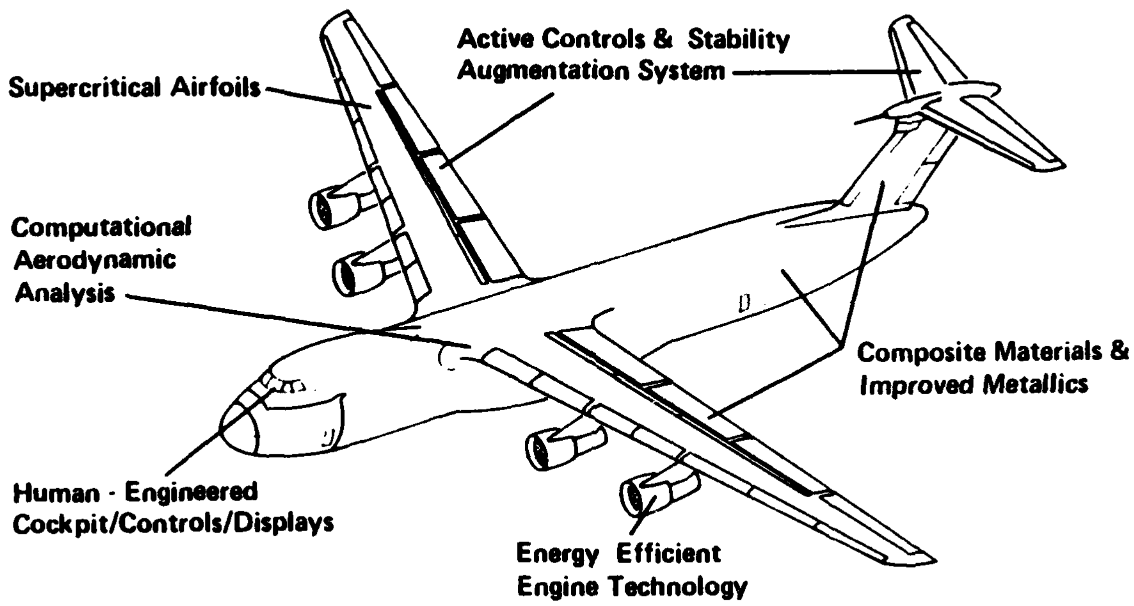

Figure 2. Technology Level Incorporated in Baseline Aircraft

Other significant technology assumptions are in the fields of aerodynamics, propulsion, and stability and control. Application of supercritical airfoil technology permits thicker wing sections, hence lower wing weights, than would otherwise be possible. Propulsion technology corresponds to that of the Pratt and Whitney STF 477 advanced-technology turbofan engine, initially described in fuel conservation studies sponsored by NASA between 1974 and 1976. This engine incorporates new fan, compressor, combustor, and turbine technologies; as well as advanced structures and active clearance control for higher efficiencies, lower fuel consumption, and improved deterioration rates.

That economies of scale also benefit the commonality concept can be illustrated with the use of Figure 3, which was originally developed to assist in the identification of the most appropriate design-payload options. Previous work had indicated that the expected advances in technology would be insufficient to justify a new airplane in terms of commercial economics unless it had significantly greater capability than the 747-200F. As shown in Figure 3, a three-stick cross-section (i.e., the capability to load containers three abreast) is the next logical step in aircraft size. After examining the spectrum of possible payloads, for a three-stick configuration, our analysis suggested a payload between 360,000 and 390,000 pounds as being most appropriate.

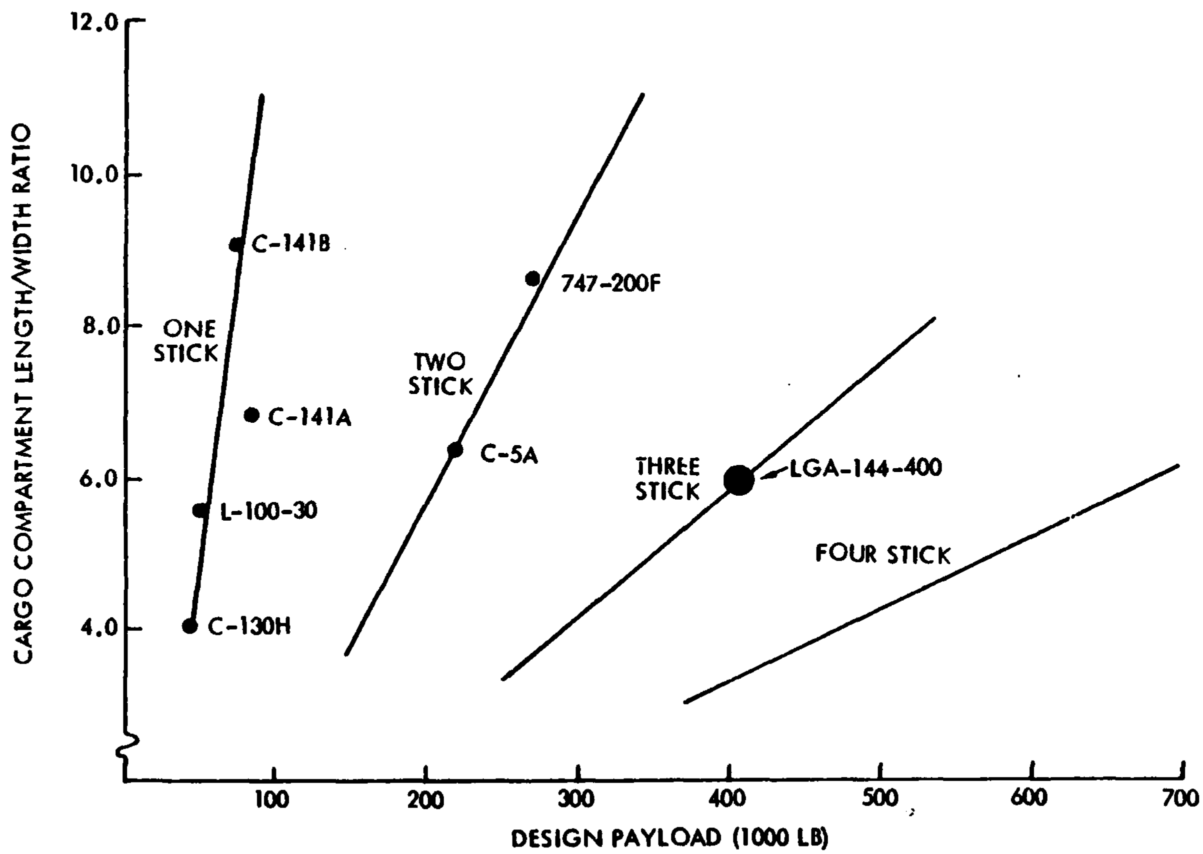

Figure 3. Considerations Related to Economies of Scale

From the viewpoint of civil/military commonality, payload is of great significance. Consider first, payloads in the one-stick-aircraft class. Although potentially interesting commercial configurations could be developed, none would be particularly useful militarily since they could probably carry only a few, if any, of the various types of tracked Army vehicles.

Carriage of a tank requires an absolute minimum cargo compartment width of 12.5 feet (i.e., one-and-a-half sticks), as proven in the recent experience of the AMST prototypes. In this case, the aircraft might be attractive to the military, but would be of little commercial interest since none of the existing unit-load devices (e.g., containers) can effectively utilize a 12.5-foot-wide cargo compartment.

Thus, two sticks would appear to represent the minimum width for a viable common civil/military aircraft. Nonetheless, non-trivial penalties may still be present in this case. The current work suggests, however, that such penalties become very small in the case of a three-stick configuration.

Finally, consider the impact of careful design in terms of a three-stick aircraft incorporating the described technology level. Table 4 presents the summary results of one of the design features examined in detail; namely, whether or not the ACMA should incorporate a rear aperture. Shown are the effects of eliminating the rear aperture in terms of what are thought to be some of the most significant figures of merit.

Not surprisingly, eliminating the rear aperture provides substantial improvements in commercial economics, about 7 percent in DOC. A similar improvement in military life-cycle costs is estimated. However, note in the military case that the savings in life-cycle cost is greater than the degradation in military effectiveness. Thus, in terms of cost-effectiveness, including a rear door as well as a front door in the ACMA may not be attractive. Of course, if an air drop capability is required, then a rear aperture is essential.

Table 4 demonstrates that design features that are sometimes cited as hindering the commonality concept can be shown to actually favor commonality. The

remaining question, therefore, is whether a common configuration can be developed that not only minimizes the penalties of commonality, but that also promises sufficiently superior economics to be competitive in the commercial market place. Some insights into the answer to this question are provided at the end of this Executive Summary.

TABLE 4
EFFECT OF ELIMINATING AFT APERTURE

MODEL NUMBER	LGA-144-200	LGA-144-211
Aft Aperture	Yes	No
MILITARY CONSIDERATIONS		
Payload Fraction	0.356	+5.9%
Life-Cycle Costs ($ Bil)	32.1	-7.2%
NATO Effectiveness (Tons/Day)	23,300	-3.2%
Cost-Effectiveness ($ Mil/Tons/Day)	1.377	-4.2%
COMMERCIAL CONSIDERATIONS		
Fuel Economy (TNM/Gal)	20.8	+9.4%
Unit Price ($ Mil)	77.6	-3.0%
DOC (¢/ATNM)	6.12	-7.3%
DOC + ROI (¢/ATNM)	10.00	-7.0%

SUMMARY OBSERVATIONS

Summary observations based on the present work are in two categories: first, those related to the specific objectives of the Design Options Study; and second, those that illuminate the ultimate merit of a joint civil/military transport aircraft.

Design Options Study Objectives

The results of the qualitative assessment and the detailed analysis of selected design features and associated options should prove useful to Air Force decision makers as well as to potential civil operators.

Although the qualitative assessment represents significant progress in identifying the design features and options of interest to a joint transport program, much work in this area is still required. Specifically, additional inputs from a broad range of users, particularly from the commercial sector, are required to establish the ultimate credibility of the assessment. The primary motivation for broadening the base of the assessment is mainly related to the subjective nature of this type of analysis.

The detailed analyses of design options performed thus far are merely the "tip of the iceberg" of analyses of this type which must be performed before the functional specifications of the AMCA can be finalized. Nonetheless, results presented in this report will be useful for more clearly focusing on some initial system specifications. Also of importance is our demonstration that the implications of relatively small changes to the aircraft configuration can be successfully explored at the conceptual design levels in a quantitative context.

Viability of a Joint Civil/Military Transport

As discussed earlier in this Executive Summary, the design aspects of the ACMA appear to be wholly tractable. As also noted earlier, however, the ultimate success of a joint civil/military aircraft hinges on its economic competitiveness. To illustrate the potential of the ACMA in this regard, one of the baseline aircraft configurations developed in the present effort is compared with a contemporary aircraft.

Figure 4 displays the general arrangement of an aircraft configuration designated as the LGA-144-400. The aircraft shown in Figure 4 should not be thought of as Lockheed-Georgia's final recommendation for the ACMA but rather, illustrative of what is possible for this payload class and technology level.

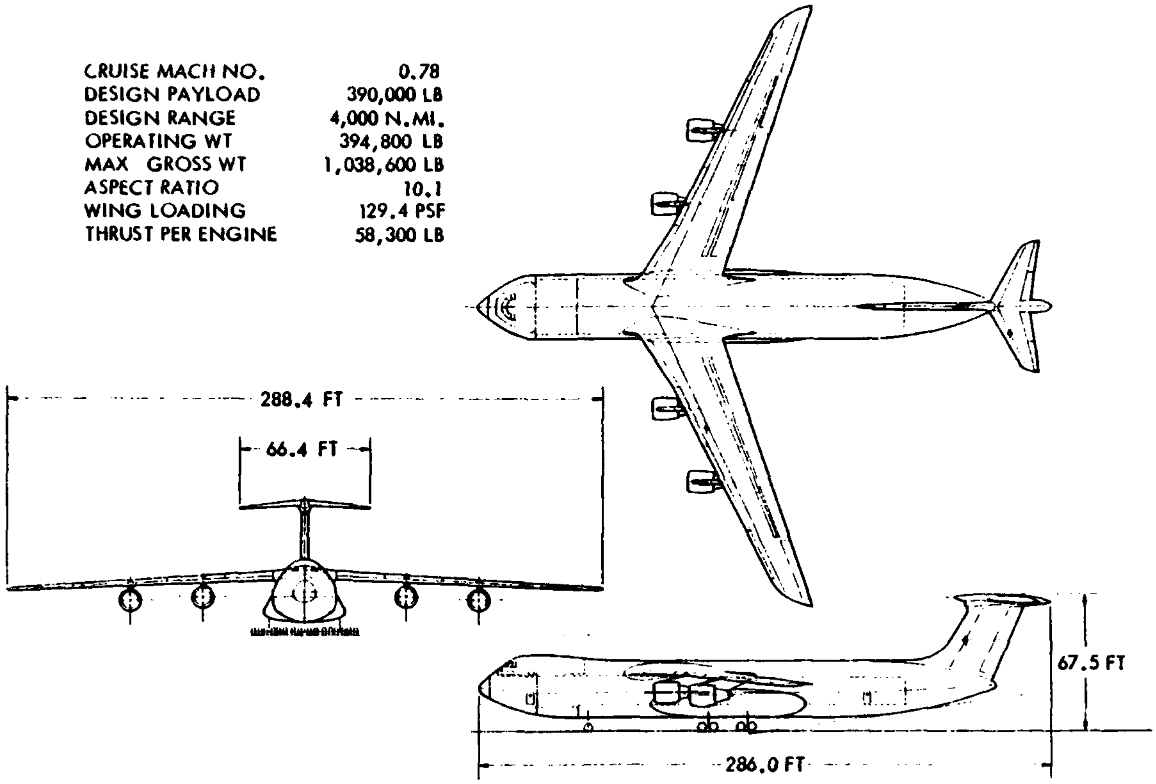

Figure 4. LGA-144-400: General Arrangement

The estimated commercial economics of the LGA-144-400 are presented in Figure 5 relative to those of the 747-200F—the most efficient commercial air freighter presently available. Note first that the LGA-144-400 would not be an inexpensive airplane to acquire. Specifically, the total Research, Development, Test, and Evaluation (RDT&E) costs for an aircraft such as that depicted in Figure 4 would be approximately 4 billion FY80 dollars; unit flyaway costs based on a production run of 250 aircraft are estimated at $85 million. Nonetheless, Figure 5 indicates that the LGA-144-400 would be only slightly higher in price than the 747 when considered per ton of payload capability.

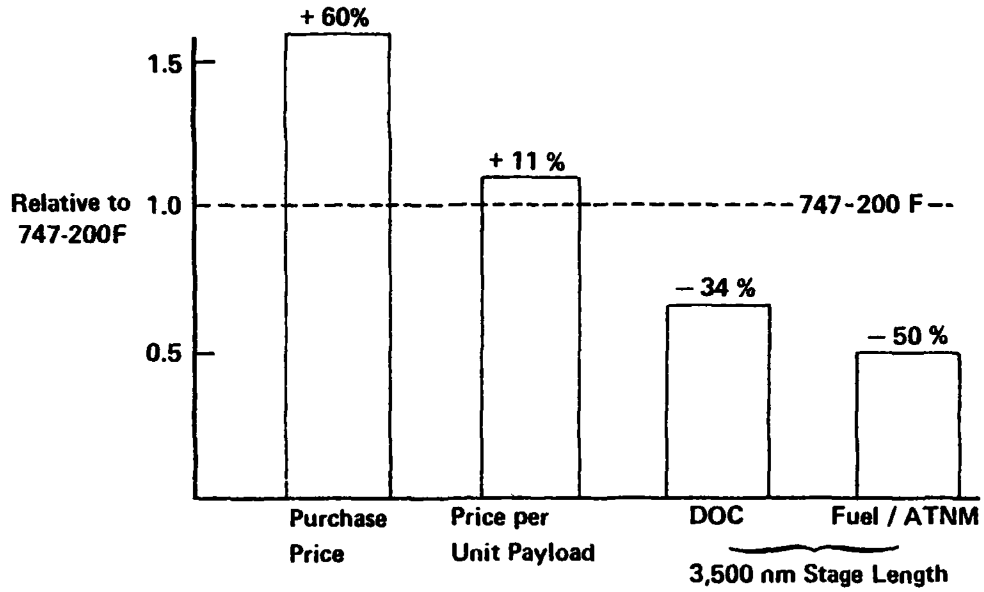

Figure 5. Commercial Economics of the LGA-144-400 Relative to Contemporary Aircraft

The real payoff of advanced technology and economies of scale can be seen in operating costs. As shown in Figure 5, a 34 percent improvement in direct operating cost can be expected from the LGA-144-400. Somewhat more than half of the improvement (about 20 percent in absolute terms) is directly attributable to the advanced technology incorporated in this ACMA candidate. The remainder is about equally split between the effects of economies of scale and the design characteristics of the aircraft.

Of course, the improvement in DOC shown in Figure 5 must be viewed with caution in the sense that the estimates for the 747-200F are based on the present-day configuration; in the future, certain advanced technologies could also be incorporated in derivatives of this contemporary aircraft. For example, improved engines could be installed with presumably, an improvement in DOC. Recall, however, that the technology that contributes the most to the superiority of the new airplanes is the assumed use of composites in primary as well as secondary structure. Blending composite technology into an existing design will, needless to say, have a smaller impact than in the case of a new design.

However, the effect of improving the contemporary airplane on the comparisons presented in Figure 5 could be largely balanced by one additional consideration. The DOC estimates in Figure 5 are based on an assumed fuel cost of $0.60 per gallon--certainly low by recent experience. Figure 5 also illustrates the differences in fuel efficiency between the contemporary airplane and the LGA-144-400. Note that the ACMA candidate consumes about 50 percent less fuel per available ton-nautical mile than the 747-200F. Thus, as fuel prices increase beyond $1 per gallon, the DOC improvement can be expected to increase from 34 percent to almost 40 percent!

In closing, a final comment on the physical size of the aircraft examined in this study is worthwhile. Several times in this Executive Summary mention has been made of the benefits of economies of scale. To put the size of these aircraft in perspective, however, Figure 6 compares the characteristics of the C-5A and the LGA-144-400. Except for the greater wing span, there are no dramatic increases in any physical dimension for the LGA-144-400. (The greater wing span, and concomitant increase in aspect ratio, is an essential element to the improved fuel efficiency.) A new aircraft of this size should present relatively few problems in terms of compatiblity with existing ground systems.

These final comparisons suggest that not only is the concept of a joint civil/military transport aircraft very promising, but that the general configurations investigated in this effort are quite credible ACMA candidates.

	C-5A	LGA-144-400
DESIGN PAYLOAD (LBS)	220,000	390,000
DESIGN RANGE (NM)	3,250	4,000
GROSS WEIGHT (LBS)	769,000	1,038,600
WING SPAN (FT)	223	288
LENGTH (FT)	248	286

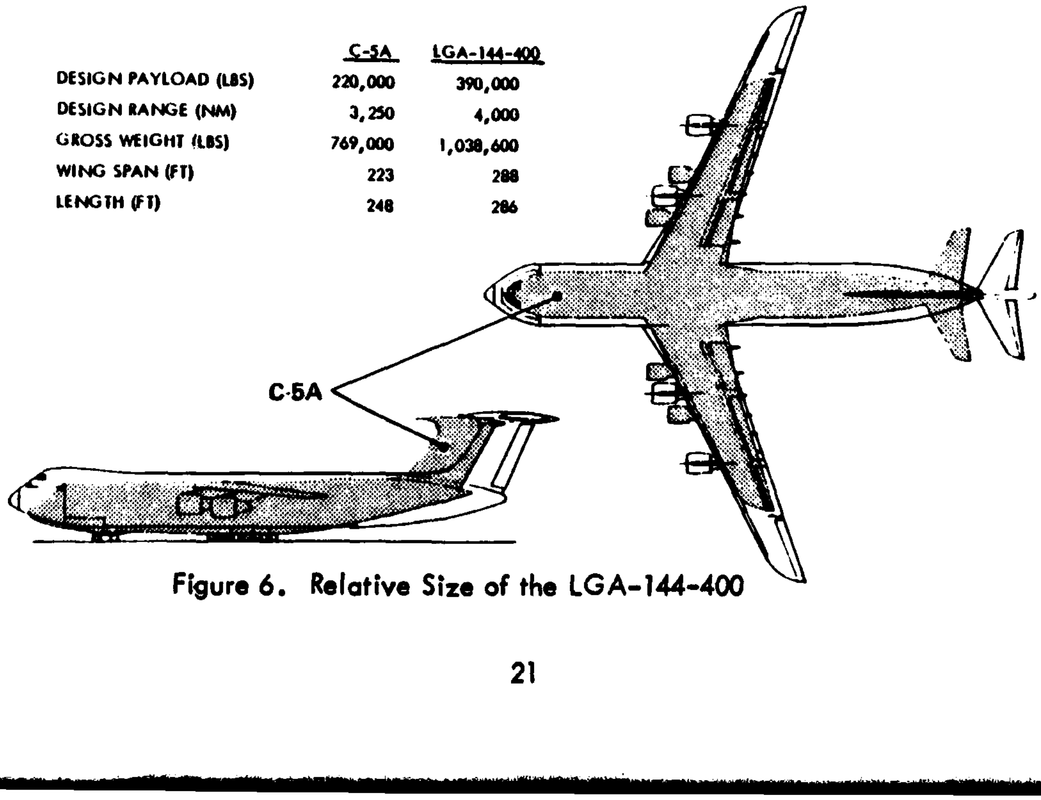

Figure 6. Relative Size of the LGA-144-400